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THE HOME STUDY OF CORAL REEFS*

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3. *Barrier Reefs and Atolls on Still-standing Islands.*[8] The shore of an oceanic island, newly formed by volcanic eruption, and then suffering no change of level as a result of subsidence or of elevation of the ocean bed from which it was built up, may be colonized by floating coral larvæ, and, as result, a fringing reef will be formed around it. The reef may then grow outward on its own talus, while its inner part is dissolved away, leaving a lagoon; thus the fringing reef will be converted into a barrier reef. In the meantime the central volcanic island will be worn down lower and lower; and eventually, after a long continued enlargement of the reef by outward growth and of the lagoon by solution, the central island may disappear, and the barrier reef will then become an atoll. This theory, like the preceding one, is based upon the improbable postulate of an unchanging ocean bed and still-standing islands. It then proceeds by easily imagined steps, but its consequences are incompletely stated. It is eminently possible that a reef may grow outward on its own talus; but if so, the entire mass of the reef must have a steep-dipping talus structure, probably disordered by slips and slides, but nowhere showing horizontal stratification. The detailed outline of the outgrowing reef will be more or less affected by winds and currents, as in the case of atolls, above mentioned; but the larger outlines will be chiefly determined by the form of the

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* Continued from the August *Bulletin*, pp. 561-577.

[8] Sir J. Murray: On the Structure and Origin of Coral Reefs and Islands, *Proc. Roy. Soc., Edinb.*, Vol. 9, 1880, pp. 505-518.

island that the reef encloses. The submarine part of the reef should rest upon a non-eroded volcanic slope. It is theoretically possible that solution may dissolve away the inner border of a reef, where coral growth is weak or absent, and thus enlarge a lagoon; but it has already been stated that the deposits of the lagoon bottom do not favor the supposition that its entire area results from the removal of pre-existent reef-limestone by dissolving it out.

A central volcanic island may be conceived as standing still while a surrounding reef grows outward; but if so, many members of its flora and fauna must be only accidentally related to those of neighboring islands, as a result of haphazard transportation back and forth in recent as well as in earlier times; they will not show those systematic relationships which are said to exist in certain island groups, and which are only explicable by slow evolutionary variation from common ancient ancestors without modern intermixture: this important principle will be further considered in connection with the sixth theory here listed. Again, islands outside of the coral seas, and hence not protected by reefs, ought to have platforms cut around their shores by the waves, as is more fully considered under the next theory.

Furthermore, if the central island of a reef stands still, any initial embayments of the shore line, due to irregularity of volcanic growth, will soon be filled with gravel, sand and mud; and deltas will be thereafter built forward on the initial reef or in the lagoon at a rate proportional to their drainage area. It is here important to note that the deltas will not be at the head of bays, for bays, apart from those due to initial inequality of volcanic construction or engulfment, do not exist on volcanic islands that have not subsided. The deltas will form salients outside of the simple perimeter of the initial volcanic cone. As they are built farther forward, they will widen laterally, and eventually unite in a confluent alluvial lowland around the island, wider in front of the valleys, narrower in front of the ridges and spurs; and at the same time the central island will be slowly worn down to fainter and fainter relief, and its deltas may ultimately be removed by the lagoon waters, and then an atoll would result; but if all of the many existing atolls have been thus formed, many examples of barrier reefs should be found in which the central islands show subdued forms and low relief in the slowly changing, long lasting, penultimate stages of almost complete degradation; and in the completed atolls, volcanic rocks should be found by boring through a thin cover of calcareous muds in the center of the lagoon.

These consequences are very imperfectly matched by the facts. Tahiti is instanced as possessing an alluvial lowland around the base of its dissected volcanic mass, and thus as confirming this theory. Darwin recognized this many years ago, and interpreted it as indicating a pause in subsidence;[9] but he recognized also that such alluvial lowlands were not of common occurrence around the central islands of barrier reefs, most of which have embayed shore lines; hence, after considering the possibility of outward reef-growth around a still-standing central island, he properly discarded it as of rare occurrence. No good examples of vanishing central islands, worn down to low relief as demanded in the penultimate stage of this theory, are known, although in view of the common occurrence of atolls they should be abundant; hence it is improbable that actual atolls represent the ultimate stage. The borings in the lagoon of Funafuti, to depths of over a hundred feet beneath its floor, did not discover volcanic rock; hence this atoll cannot be built around a worn-down, still-standing volcanic island. In this connection we may quote the opinion of Hedley and Taylor, regarding the Great Barrier Reef, northeast of Australia, to the effect that if the reef had been built outward during a still-stand of the mainland, the mainland border should now be worn down to a peneplain and fronted with deltas; but, as a matter of fact, good-sized hills still enclose the valleys, which mouth in embayments, the outlines of which have as yet hardly been softened by the deposit of sediment along their shores, though there are alluvial flats at the same bayheads.[10]

The structure of uplifted reefs is so imperfectly described—perhaps because the observers of these significant structures had not consciously deduced the contrasted consequences of rival theories—that it cannot be safely used in the present discussion; but as far as I have read, there is no well attested example of an uplifted reef which consists wholly of outward-slanting talus layers. Some uplifted reefs seem to have been built on eroded surfaces, and this implies subsidence before or during the growth of the reef, as will be further considered in a later section.

This theory is therefore, to say the least, not proved to be a counterpart of nature, unless in local, special and exceptional cases. It is ingeniously contrived; but its leading postulate of a still-standing central island is not tested by an examination of the flora and fauna or of the shore lines of the central islands enclosed by barrier reefs; if it were thus tested it would, if we may accept the conclusions of certain zoologists, be in nearly all cases contradicted. One of the essential consequences of the theory—the occurrence of alluvial lowlands around the inner border of the lagoon—is of decidedly exceptional occurrence; another—the rough bottom of the lagoon, as a result of solution—does not correspond to the facts; others, as to internal structure, are not now confirmable, because the corresponding facts are invisible in actual barrier reefs, and imperfectly determined in uplifted reefs. The theory would be improved, if it were amended by replacing the postulate of a still-standing island by a slowly subsiding island, but that would transform it into the theory here numbered 6. Judgment must therefore be pronounced against it, except in special cases where alluvial lowlands occur within the lagoon; and even in these cases, the still-stand thus indicated may be only a pause in a prolonged subsidence.

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[9] Coral Reefs, p. 128.

[10] Coral Reefs of the Great Barrier, Queensland ... *Proc. Austr. Assoc. Adv. Sci.*, Vol. XI, pp. 907, 397–413; see pp. 410–411.

4. *Veneering Reefs on Sea-cut Platforms.*[11] A still-standing island, attacked by the sea and unprotected by a growing reef, will have a platform cut at a moderate depth all around its border; a reef may then be built on the outer border of the platform, enclosing a lagoon; thus a barrier reef will be formed without subsidence or outward growth. This theory is based on the tacit postulate that corals shall not establish themselves until the platform has gained a considerable width; this appears unreasonable, inasmuch as newly established, discontinuous fringing reefs have been observed on the uncliffed shores of a young, slightly dissected volcanic cone in the island of Mehetia, east of Tahiti.[12] Several essential consequences of this hypothesis, not stated, however, by its advocates, are that the island should rise in steep cliffs from the inner border of the sea-cut platform, as was pointed out by Darwin in 1842; that islands of this form should occur outside of the coral seas, and the older the island, the broader its platform; that, after a barrier reef is established on the outer border of the platform, enclosing a shallow lagoon, a talus should accumulate at the base of the cliffs and deltas should be built forth from valley mouths; and that uplifted reefs of this kind should have small thickness on the outer border of a nearly horizontal bench of volcanic rock which contours around the fading cliffs of the central mass. The floræ and faunæ of neighbor-

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[11] Journal of Voyages and Travels. By the Rev. Daniel Tyerman and George Bennet. Deputed from the London Missionary Society to visit their various stations in the South Sea Islands, China, India, etc., between 1821 and 1829. 3 vols. Vol. I, p. 215. Crocker & Brewster Boston, 1832. (This reference is taken from Darwin's "Coral Reefs.")

[12] A. Agassiz, *Mem. Mus. Comp. Zool.*, XXVIII, 1903, p. 140.

ing islands should be accidentally related, as stated under the previous theories; but this requirement is contradicted by the facts, as far as they have been closely studied. Furthermore, no cliffed volcanic islands, surrounded by a shallow submarine platform not yet colonized by corals, and no barrier reefs around a lagoon with a cliffed central island are known in the coral-reef regions: hence this theory has seldom found favor.

The postulate of a still-standing central island has already been shown to be improbable; no independent evidence is presented to show that the postulate is reasonably acceptable in the islands to which the theory has been applied. The action of the sea in cutting a platform around an undefended volcanic island is not to be denied, but when the features appropriate to such action—a central island with a sea-cliffed margin—are looked for, features of quite another kind are found. It is important to recognize that the cliffs, which must necessarily rise from the inner border of a wave-cut platform on a volcanic island that has not suffered subsidence, will not truncate promontories between bays, for, as already stated, bays, apart from those due to the initial inequalities of the volcanic cone, do not occur on volcanic islands that have not subsided. The cliffs at the inner border of a sea-cut platform will usually have a somewhat simpler outline than the initial circle or oval of the volcanic cone; they will be less developed on beds of resistant lavas, and more developed on beds of loose ashes. If the volcano is young and the platform is narrow, the cliffs will be relatively immature, ragged and low, and will be interrupted only by narrow, young gorges; if the volcano is longer extinct and the platform is wide, the cliffs will be high because they will have been cut far back into the conical island; and they will be interrupted by broadly opened valleys, because the time required for cutting a wide platform will be long enough for the mature dissection of the cone. These are systematic relations which deserve conscious consideration in the study of central islands within barrier reefs; they illustrate a modern phase of rational geography, in which the systematic evolution of land forms is fully recognized, just as the biotic relations of neighboring islands, briefly mentioned above and more fully treated under the sixth theory of this list, illustrate a modern phase of rational biology, in which the systematic evolution of organic forms is fully recognized. There was a time, not long ago, when land forms, like organic forms, were thought to be outside of an investigator's responsibility, because they were taken to have been made about as we now see them. The general adoption of an evolutionary philosophy has changed all that, and land forms are now seen to be the result of inorganic evolution, and hence to be fit subjects for intelligent study, just as plant and animal forms are seen to be the result of organic evolution.

The tacit postulate of the delayed colonization of a volcanic island by corals is inherently improbable, and no evidence is adduced to show that it may be accepted. The small thickness of the veneering reefs on the outer border of a nearly level sea-cut platform is not proved by borings, or by the features of uplifted reefs. The theory can have only a very restricted application, if it holds true at all. Adverse judgment need not be suspended.

5. *Veneering Atolls on Sea-cut Platforms.*[13] It is here assumed that a still-standing island is completely truncated and that a reef then built around the border of the truncating platform forms an atoll. As in the preceding theory, a tacit postulate is here made that corals shall not establish themselves on the border of the platform until the sea has completed its work of truncation, and so long a postponement of their arrival is certainly unreasonable. If the numerous atolls of the Pacific had been formed in this way, borings should show volcanic rocks at small depth beneath the whole of the lagoon; some nearly and some completely truncated volcanic islands should occur in the temperate oceans, outside of the coral zone; and, above all, some examples of penultimate truncation should occur in the coral seas, showing cliffed island remnants rising above a broad and shallow platform without reefs. None of these consequences are, as far as I have been able to learn, confirmed by the facts. It is true that the charts of our Hydrographic Office show some singular, residual, spine-like rocks, much higher than they are broad, rising from the sea south of Japan; one, known as Lot's Wife (29°45′ N., 140°20′ E.), is 466 feet high, with no bottom at twenty fathoms close around it; another, Smith Island (31°30′ N., 140°0′ E.), is 421 feet high, with depths over 100 and 200 fathoms near by it. Both these rocks have overhanging profiles on one side; they seem to resemble the famous volcanic spine of Montagne Pelée, and may have lost the weaker, fragmental material with which their base was originally enclosed; but they do not appear to correspond to a late stage in the truncation of a large island, for they are not surrounded by a shallow platform. The flat platforms, in the Pacific, without coral reefs rising to the surface, which suggested this theory, might be as well explained as former atolls, too rapidly depressed to be built up, as Darwin long ago suggested for the Chagos Bank. This theory

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[13] Rear Admiral W. J. L. Wharton: . . . *Nature*, Vol. LV, 1897, pp. 390-393.

has therefore found little favor. Comments similar to those made on the preceding theory apply here with equal force.

6. *Reefs Built on Subsiding Islands.*[14] This theory postulates in its simplest form that the islands "on which the reefs first became attached, slowly and successively sank beneath the sea, whilst the reefs continued to grow upward"; thus a fringing reef will be transformed into a barrier reef enclosing a lagoon around a diminished island, and into an atoll, after the island disappears.

Let it be here noted that the term coral reef, as used by Darwin and indeed by most other writers, has two meanings:—one is the visible belt of corals with a small thickness of coral limestone beneath; the other is the whole mass which, it is inferred, is added to a volcanic island to produce a fringing or barrier reef, and which therefore includes the interior lagoon deposits and the exterior talus deposits, along with the coral limestone that has been formed, according to the present theory, during the upgrowth of the reef proper. It is important to recognize this double meaning, because some recent studies suggest the separation of the reef in its smaller meaning from the larger understructure, and propose for the whole of the latter, the greater part of which is presumably not composed of coral rock but of lagoon and talus deposits, the name platform. It is, however, not yet shown that coral rock does not extend downward about as deep as the outer part of the platform, or that the reef and the platform have not been formed together, essentially in the manner that Darwin supposed. It should not be overlooked that Darwin clearly recognized the strong difference between the calcareous muds of the lagoons and the coral rock of the reef proper; he recognized also the abundant growth of nullipores in association with reef-making corals, though he did not give to these calcareous algæ the importance that has been ascribed to them in recent years; he naturally knew nothing of the recently discovered action of bacteria in forming the oölitic muds of the lagoon, and he did not discover that the platform in some cases extends along a continental margin farther into temperate latitudes than the limits of the coral zone; for example, southward along the eastern coast of Australia, as was shown by Andrews twelve years ago, and northward along the eastern coast of Florida, as has recently been pointed out by Vaughan. But, let it be repeated, there is at present no sufficient reason for rejecting the idea that, in waters warm enough for the growth of reef-building corals, the reef and the platform have had essentially their present relation during the entire period of formation of a barrier reef in the larger sense of that term. It is therefore, in my judgment, going too far to say that "an inspection of the admiralty charts for the eastern coast of Australia shows conclusively.....that corals have established themselves on this platform where the conditions favorable for their life were realized," and that "a study of the charts of barrier reef islands... shows that the platforms are independent of the presence of the reefs....for here the reefs are also superimposed on platforms antedating their presence."[15] The occurrence of many uplifted reefs at successive altitudes on certain islands, as in the Philippines, shows that reef-building corals have been, for a long time, growing in the coral seas; hence, if the platform of a barrier reef were formed during slow subsidence, as is eminently probable in the Australian reef, at least, a coral reef may have occupied its margin during the whole period of its growth, just as it does now; and in such case the reef would not be superposed on the finished platform, but would have grown up with it.

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[14] C. Darwin: The Structure and Distribution of Coral Reefs. London, 1842; 2d edition, 1874.

Before going farther it should be pointed out that Darwin's postulate of general subsidence over large areas may have to be modified in view of facts discovered since his time; but it should, at the same time, be noted that such modification of his theory by no means invalidates its essential principle, although it makes the action of subsidence in the Pacific Ocean less simple than he regards it in his first paper on this subject.[16] Certain objections that have been urged against Darwin's main postulate are nevertheless irrelevant; for example, it has been urged that, because elevation is proved by high-standing reefs in certain regions, therefore subsidence has not taken place in certain other regions; it would be as fair to argue that, as subsidence is proved by the drowned valleys of certain oceanic islands, therefore high-standing reefs have not been elevated, or to argue that, because high-standing reefs are usually of moderate thickness, therefore barrier reefs cannot generally be of great thickness. Indeed, certain high-standing reefs are found to contour around a previously eroded land surface, instead of resting on a non-eroded surface as is required by the third theory here discussed, and they thus prove that, before elevation, subsidence took place to at least as great a measure as the difference of altitude of the lowest and the highest reefs; and in such a case it must remain an open question, until new details are observed, whether the reefs were formed from lowest to highest during pauses in the subsidence by which the eroded land surface was submerged, or from highest to lowest during pauses in the elevation by which the reefs were uplifted; or some during subsidence and others during elevation. It may not always be easy to recognize whether the contact of the reef with the preexistent land surface is unconformable or not; it must be still more difficult to determine, in cases where uncomformable contacts are found, whether a given reef was formed during subsidence or elevation. Surely not until the nature of the contact of an elevated reef with its foundation has been determined, is it permissible to infer that it testifies only to elevation, and not to subsidence as well.

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[15] T. W. Vaughan, *Journ. Wash. Acad. Sci.*, Vol. IV, 1914, pp. 32, 33.

[16] C. Darwin: On certain areas of elevation and subsidence in the Pacific and Indian Oceans, as deduced from the study of coral formations, *Proc. Geol. Soc., London*, Vol. II, 1837, pp. 552-554.

Another invalid objection that has been urged against the theory of subsidence is that, although a movement of depression may occur in ocean basins on either side of or between groups of volcanic islands, such movement should not be expected on the very site of such islands; but this implies a much fuller knowledge of the relation between vulcanism and diastrophism than we now possess. Subsidence, even of groups of volcanic islands, is, in view of all that is known of the history of oceanic islands, like elevation, a more likely condition than a still-stand.

Besides the consequences that are involved in the statement of his theory of subsidence, Darwin deduced certain others, especially regarding the submarine structure of the total mass: he pointed out that the reef proper ''would consist of massive species [of coral] in a vertical position, with their interstices filled up with detritus''; that in the lagoon area ''a very large proportion of the rock, and, in some cases nearly all of it, would be formed of sedimentary matter, being in an excessively fine or moderately coarse state''; that ''the stratification, taken as a whole, would be horizontal''—the outward-sloping layers of an exterior talus do not seem to have been given special attention—and that in an uplifted reef the horizontal lagoon strata ''would more often be preserved to future ages, than the exterior solid reef composed of massive corals in an upright position.'' These consequences were announced only in a foot note at the end of the fifth chapter of ''Coral Reefs,'' probably because the facts with which they should be confronted were, for the most part, inaccessible; but the contrast here indicated between the mainly horizontal structure of reefs formed during subsidence and the mainly inclined structure of reefs formed by outward growth on their own talus is evidently of critical importance in the study of uplifted reefs. Another consequence of subsidence is that the reef-mass should be built unconformably upon a surface of subaërial erosion and not upon one of submarine deposition, as has been alluded to above. Unfortunately, so little is now known of the structure of uplifted reefs that they cannot be safely used at present as indicating the origin of reefs that are not uplifted. It would, however, surely seem that the horizontal attitude of the lagoon strata, the occurrence of interbedded sands and gravels near the central island, and the form of the island surface beneath the reef-mass must be critically significant of the conditions under which an uplifted reef was formed. In the case of atolls, borings might detect cross-bedded beach or dune stratification, and an alternation of calcareous layers with guano deposits.

It should be noted that Darwin carefully guarded himself against an undue preference for his own theory by an impartial examination of many others, including those here numbered 1, 3 (omitting solution of the lagoon), 4 and 5, all of which he rejected on good grounds, although recognizing the process of moderate outward growth on a still-standing island as applicable to the island of Tahiti, and, in that case, substituting for the postulate of uniform subsidence the more natural one of subsidence alternating with intervals of rest (Coral Reefs, pp. 128, 130). His readiness to revise his theory is shown in the second edition of his book (1874), in which, as a result of Semper's observations on the Pelew Islands, alternations of elevation and subsidence were recognized as reasonable and possible, if elevated reefs and barrier reefs occur in the same region.

Indeed, after a careful review of many essays on the problem of coral reefs, Darwin's discussion of it in his little book of 1842—to the preparation of which he devoted twenty months of hard work—seems to me more broad-minded and more critical than any other. The great naturalist clearly recognized the desirability of "searching for other evidence of the movements" postulated in his theory, but he adds that "from the nature of things, it is scarcely possible to detect any direct proof of subsidence, although some appearances are strongly in favor of it" (Coral Reefs, p. 147).

There are, however, certain additional and important consequences of the theory of subsidence which were not deduced by its author. One is that subsidence must separate an originally single large island of irregular mountainous form into a group of smaller islands, on which certain members of the fauna and flora—namely, those which cannot migrate and cannot be accidentally transported by wind or water—should show the peculiar resemblances and differences appropriate to a gradual and long continued evolutionary change from common ancestral forms on an ancient continuous habitat to a modern discontinuous habitat. It may at first thought seem strange that, of all observers, Darwin should have overlooked so significant a matter as this; but it must be remembered that, while he was studying coral reefs, he was not a Darwinian but a special creationist, for when he visited Valparaiso during the voyage of the *Beagle* eighty years ago, he wrote: ''I have taken several walks in the country . . . there are very few quadrupeds and birds are not plentiful . . . . I have already found beds of recent shells, yet retaining their colors, at an elevation of 1,300 feet, and beneath this level the country is strewed with them. It seems not a very improbable conjecture that the want of animals may be owing to none having been created since this country was raised from the sea.'' Under the influence of that ancient biological philosophy, the relationships of the fauna and flora on neighboring islands would have no bearing on the origin of the associated barrier reefs; but under an evolutionary philosophy, it is just as essential that certain plants and animals on islands, surrounded by barrier reefs formed during subsidence, should possess peculiar relationships due to descent from common ancestral forms, as that the shore lines of the islands should, as Dana pointed out, be embayed by the drowning of their valleys.

This line of biological evidence, already briefly referred to, is not so well appreciated by geographers and geologists as by the circle of biologists who have elaborated it. Indeed, the conclusion to which the evidence leads is objected to by some students of earth structure, who, having reached from geological considerations the conviction that continental masses and ocean basins are long-lasting, almost permanent terrestrial features, are therefore disinclined to accept the possibility that a former large land area has sunk to great oceanic depths, particularly if the evidence for so great a change is based only on the distribution of small animals. As against this disinclination it must be recognized that the theory of the permanence of continental masses and ocean basins is based as well on our unavoidable ignorance of crustal structures over the three oceanic quarters of the earth's surface, as on our growing but not yet full-grown knowledge of the remaining continental quarter; it may be further said that the disappearance of various full-fledged mountain structures in the sea, as northeast of Newfoundland, southwest of Ireland, or west of Brittany, and the lateral truncation of large geosynclines by the present continental margin, as in southeastern

Africa, strongly suggest that parts of former continents are now deeply submerged; and finally it should be urged that the detailed biological evidence in favor of extensive submergence is fully as worthy of serious consideration as the general geological evidence against it. The character of the biological evidence is, in essence, as follows:

Imagine several neighboring islands, each of which possesses certain similar yet distinct forms of plants or animals. That these forms were so created, each on its own island, no longer finds a place in biological speculation; for whether the processes of evolution are understood or not, it is agreed on all sides that similar plants or animals are the descendants of common ancestral forms: hence some rational method of accounting for the present distribution of the related forms must be looked for. There are two chief methods: one postulates a still-stand of the islands and some relatively accidental means of transportation, as by tree rafts or storm winds, by which individuals of an ancestral form were carried to the several islands long enough ago for the observed specific differences to have been since then evolved. Two difficulties stand in the way of this method: the first is that no available means of accidental transportation for certain plants or animals across an open water passage can be reasonably imagined, because they are too delicate to survive the exposure to which they would thus be subjected; the second is that, if accidental transportation were formerly available, it ought to operate in modern times as well, and thus produce on each member of an island group, an arbitrarily mixed flora and fauna, including species of recent introduction, that are identical with forms of neighboring islands and species of much earlier introduction that are like but not identical with forms on neighboring islands; for forms of recent transportation from one island to another would necessarily be alike, while those of ancient transportation would now have become unlike. Hence, on islands where such mixtures of species do not occur, this method of distribution must be rejected.

The other method of distribution postulates, first, a former land connection between the now separated islands, and the occurrence of the ancestral species all over this continuous habitat; then a disruption of the land connection in any manner, as by folding, faulting or subsiding, so that several groups of the ancestral species are isolated; thereafter each group varies in its own fashion, and thus the modern differences of the related species are evolved. A standard example of this kind is that of the cassowaries on the islands north of Australia, described by Beddard in his ''Zoogeography.''

It is not here possible to mention additional examples of plants and animals on the central islands of neighboring barrier reefs, which indicate the disruption of a former continuous land area by subsidence and which thus give independent confirmation of Darwin's theory explanation of the encircling reefs; but it may be noted that the biologists who have looked most closely into this problem, on the basis of carefully collected specimens, are convinced that isolation by subsidence is its only solution. It may, however, be suggested that the critical point in this argument is the determination of ''identical'' and of ''related but not identical'' forms in species not subject to accidental transportation. It would therefore be fair to demand that identity and resemblance should be so sharply differentiated that, if a large collection of forms in groups of a dozen from each locality, regarded as ''identical'' and as ''related but not identical'' by their collector, were mixed (each group of a dozen being kept together) without labels, they could be classified by another biologist in essentially the same species that had been previously established with the aid of the collector's labels; for if the classification depends on a knowledge of the locality, as well as on a study of the specimens, non-zoological students will hesitate to accept conclusions based on species thus made.

The most manifest consequence of the theory of subsidence that was overlooked by its inventor has already been alluded to: it is that, as an island subsides, it must not only diminish in size, but it must also acquire a more or less embayed shore line as a result of the advance of arms of the sea into its previously eroded valleys. That so evident and inevitable a consequence of subsidence should have been overlooked is singular enough, and all the more so since Darwin had recognized the occurrence of long bays entering the central islands of barrier reefs; he probably attributed them to marine erosion, after the fashion of his time. His omission was remedied by Dana,[17] who, imperfectly anticipated by De la Beche, first recognized and explicitly stated the important principle that the partial submergence of a dissected land surface must produce coastal embayments. He rightly used this principle in giving independent confirmation to Darwin's theory. It is interesting to note that Darwin came very near discovering the principle himself; for while he was in Chile he made an excursion from Valparaiso to the base of the Andes, when he noted that Chile "is traversed by several lines of high hills parallel to the great range . . . At the foot of the Andes there is a succession of level basins . . . These basins or plains, together with the flat valleys which connect them with the coast, are the bottoms of ancient inlets and great bays, such as, in the present, intersect every part of Tierra del Fuego and the west coast of Patagonia, etc. Chile, at one time, must have, in the configuration of its land and water, exactly resembled these latter countries. This resemblance was occasionally seen with great force, when a fog bank extended over the whole of the lower parts; the white vapor, curling into all the ravines, beautifully represented the little coves and bays. Here and there a solitary hillock peeped up through the mist and showed that it had formerly stood as an islet."

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[17] J. D. Dana: Corals and Coral Islands. 1st ed., 1872; 2nd ed., New York, 1879. The results of Dana's observations, made on Wilkes' Exploring Expedition (1838–1842), were previously published in his Report on Zoöphytes (1846), treating at length of coral reefs and coral animals, and in a chapter on Coral Reefs and Islands (1849) forming a part of his Geological Report in the Report of the Wilkes Expedition.

How curious that a mind as alert as Darwin's did not make the easy step from the floating fog to a rising sea! More curious still that he did not, fifteen years afterwards, notice Dana's explicit explanation of the origin of embayments by subsidence, and seize upon the confirmation thus given to his own theory; but singularly enough no use is made of Dana's principle in the second edition of Darwin's "Coral Reefs" (1874), although Dana is repeatedly quoted there on other topics. The reason for this omission is probably to be found in Darwin's absorption at that time in the discussion of the origin of species; or perhaps in the inattention of one geologist to the writings of another, regarding which Darwin wrote in 1844 or 1845 in a letter to a friend: "As for your pretending that you will read anything so dull as my pure geological descriptions, lay not such a flattering unction on my soul, for it is incredible. I have long discovered that geologists never read each other's works, and that the only object in writing a book is a proof of earnestness, and that you do not form your opinions without undergoing labor of some kind. Geology is at present very oral, and what I here say is to a great extent true." (Life and Letters, Vol. I, pp. 334, 335; Amer. edit., Vol. I, p. 303.)

(*To be concluded*)